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BAT COLLISIONS WITH HIGH PERFORMANCE AIRCRAFT

A preliminary field investigation conducted at
Randolph Air Force Base, Texas, 19-25 October 1967

Timothy C. Williams, Department of Animal Behavior
The Rockefeller University, New York, New York 10021

Janet M. Williams, Institute for Research in Animal Behavior
The Rockefeller University and the New York Zoological Society
New York, New York 10021

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At the request of the Directorate of Life Sciences, Air Force Office of Scientific Research, a study was conducted by Timothy C. and Janet M. Williams, Field Research Investigators, The Rockefeller University and the Institute for Research in Animal Behavior (The Rockefeller University and the New York Zoological Society) respectively, through support provided by contract F44620-67-C-0063, with the Office of Ecology, Smithsonian Institution, Dr. Helmut K. Buechner, Principal Investigator. This study was developed in response to a report from Colonel William D. Nettles, USAF, VC, Command Veterinarian, Air Training Command, that the possibility existed that Randolph Air Force Base T-38 aircraft were experiencing bat airstrikes.

ABSTRACT

Microscopic examination of animal remains from "birdstrikes" showed that bats account for at least some of the "birdstrikes" reported at Randolph Air Force Base, Texas.

The distribution of the Mexican Free-tailed bat during the night at ground level seems to be constant in all locations tested in and near the base; concentrations of a second species of bats, probably Myotis velifer occur around strong lights which attract insects.

Mexican Free-tailed bats emerging from the Bracken Cave near the base do so in dense clusters of 100-1000 animals; some of these bats fly at least 2000' AGL. Some of these bats or clusters of bats are identifiable on MPN 16 Radar, and areas of maximum concentration can be detected.

At night in late October the concentration of bats from ground level to 1500' averages about one bat/million cubic feet. Above 1500' the concentration of birds increases.

It is our opinion that much information regarding the density of flying animals is presently available through radar systems and that this information, if utilized, would be of vital importance to aircraft.

INTRODUCTION

Collisions of aircraft with flying animals constitute a serious hazard to personnel and equipment at Randolph Air Force Base, Texas. Investigations conducted by the Flying Safety Division of the Air Force Training Command at Randolph indicate that more than 60 per cent of all strikes occurred below 1000' above ground level (AGL) and that only one strike of 94 recorded occurred above 2500' AGL. Most strikes, therefore, occur during the critical take-off or landing phase of flight. Apparently only strikes in the engine or on the windscreen are dangerous; several windscreens have been broken and 25 engines have been rendered inoperable without repairs. These figures are for the T-38, a lightweight, high speed, training aircraft, which accounts for two-thirds of all reported "birdstrikes" and almost all instances of engine failure due to "birdstrikes". During the month of August 1967, approximately one of every 20 flights encountered a flying animal which either rendered the engine inoperative or obscured all or part of the windscreen. However, if only flights after sunset are considered (no flights being conducted during the early morning hours) then the figure jumps to one of every nine flights resulting in a "birdstrike". The preponderance of strikes at night (18 of 25 engines were lost on night flights) coupled with the peak of strikes in August, the month of maximum population of bats in the area, suggests that bats are an important factor in the collision.

A brief preliminary investigation of the hazard bats pose to high speed aircraft was conducted by the authors at Randolph Air Force Base from 19 to 25 October 1967.

MATERIALS AND METHODS

The bat detectors used in this work were of three types: (1) highly sensitive but non-tunable type developed by J. J. McCue and A. Bertolini (1964) of Lincoln Laboratories, Mass., a heterodyne unit; (2) the Holgate Ultrasonic Receiver and Microphone of Holgates of Totton Ltd., Commercial Road, Totton, Hants, England, and (3) an ultrasonic cable leak detector manufactured by DEMCO. P.O. Box 16041, San Antonio, Texas 78216. The latter two types seemed to be of equal sensitivity in detecting the bats found in the study. All three of the devices have a microphone which picks up the high frequency signals emitted by bats when echolocating. The detector then converts the high frequency signal to a lower frequency in the human audible range.

The audio output of the McCue-Bertolini detector was fed through a peak detection circuit to a 100 micro ampere Rustrack chart recorder which sampled the bat detector output once every two seconds. Visual observation of the device operating in a flood-lit area at night revealed that the system would record the presence of any bat flying through a cone-shaped area subtending roughly plus or minus 40 degrees from the principal axis of the microphone and up to about 100' from the microphone.

The Holgate and the DEMCO units were both able to distinguish between two species of bats; for one, the Mexican Free-tailed bat, Tadarida brasilensis mexicana, the detectors indicated a maximum intensity of sounds reaching the microphone at 40-60 kHz, for the other, presumably the brown bat, Myotis velifer, the maximum was at 25 kHz. Since high frequency sounds undergo extreme atmospheric attenuation, only recordings immediately in front of the bats would indicate the sounds actually emitted by them. The range and directionality of these detectors was similar to the McCue bat detector.

RESULTS

Frequency of "birdstrikes"

Examination of two aircraft, one new and the other two years old, revealed that the frequency of "birdstrikes" is probably much greater than that reported, as the older aircraft had about 150 small dents in the leading edges of the wings while the newer aircraft had only about 10. Since these dents were found primarily in the leading edges of wings and stabilizers and not on other parts of the aircraft, we presume that they occurred in flight and represent an indication of the total number of airborn objects encountered in flight.

Identification of bat remains by microscopic examination

Ingestions of flying animals by turbo-jet engines, in almost all cases, results in complete destruction of the animal matter. Animal matter is often present on the windscreen after a "birdstrike". During our stay animal remains from two nocturnal strikes were collected and subjected to microscopic examination. Due to extreme maceration and desecration of the sample, identification of fragile tissues such as blood was difficult. Of the more resistant structures, bat fur was the most easily identified. The most successful preparation seemed to be maceration of the animal remains in dilute unflamed KOH solution. The particles could then be teased apart with a fine glass needle and examined under low power for the characteristic segmented and tufted long strands of bat fur. At the time, presence of bat fur was verified by comparison with a known sample of bat fur and blood. A set of photomicrographs of bat fur, bird feathers and "birdstrike" remains is being prepared by Dr. Watson of the Randolph Base Hospital which will aid in identification of animal remains from future strikes.

Results of experiments with bat detectors

Investigation of the distribution of bats in two types of areas within the base was made with the aid of the bat detectors described previously under materials and methods.

Distribution of bats around lights

The maintenance ramps in front of the hangars on Randolph Air Force Base are illuminated by high power flood lights which attract large numbers of insects of all sizes. As might be expected bats are often seen flying in these areas catching the insects. The tunable bat detectors revealed that the majority of bats in this area emit cries reaching the microphone with a maximum intensity at 25 kHz. Only about 10 per cent of the bats in this area gave readings of 40-60 kHz, the maximum intensity range of the Mexican Free-tailed bat in tests.

The automatic recording system revealed that the bats emerged at 1915 and retired at 0600 the next day, the activity between 0500 and 0640 that morning being sporadic. The density of bats was roughly constant from 1915 to 0500; during this period one or more bats were within range of the detecting system in 80 per cent of the two second time intervals sampled by the recorder.

Distribution of bats in unlighted areas

The area on the side of the runway opposite the maintenance ramps is unlighted except for dim landing lights. This area was studied as it seemed similar to the take-off and landing areas at the ends of the runway which were unsuitable for investigation. In this area the most common bat gave bat detector readings in the 40-60 kHz range while only about 10 per cent of the observed bats gave readings of 25 kHz. Visual observation, hand held bat detectors, and recording bat detectors all indicated the density of bats to be less in the unlighted than in the lighted areas. Recordings from this area were complicated by artifacts from aircraft using the runway, but the times of bat activity in the area were similar to activity in the lighted areas. During the early morning hours when planes were not using the runway, one or more bats were within range of the detecting system, in 15-20 per cent of the two second time intervals sampled by the recorder.

These observations indicate that the density of Tadarida brasilensis mexicana is constant over the area under study while the density of bats hunting around flood lights is increased by the addition of a second species, probably Myotis velifer. Brief checks with bat detectors at a number of points on the base confirmed this general pattern.

Observations with radar

Randolph Air Force Base is equipped with a MPN - 16 Radar installation. This is a dual purpose radar with a 10 cm search radar with a range of twenty miles and MTI circuitry which indicates only targets with a velocity greater than about 30 mph, and a three cm Precision Approach Radar (PAR) with a nine mile range. The PAR is of very low sensitivity and low power and detects only large targets.

The present operators of the radar installation informed us that for at least several months they had observed what they had believed to be a thermal inversion on the search radar. This phenomenon occurred very near the location of a large bat cave 10 miles from the base at NW 320 degrees. Richard Davis (1962) has carried out extensive investigations of the Mexican Free-tailed bat in southern Texas and describes this cave (the Bracken Cave) as the largest bat roost in the area with a peak population of near 40 million animals in August.

Visual observation of the bats emerging from the cave revealed the typical pattern of a dense column of animals emerging from the cave at about sunset, twisting towards the south for perhaps one quarter of a mile and then ascending steeply in groups of between 100 and 1000 animals. Both with the unaided eye and with binoculars one gained the impression that the bats were flying at great heights but upon critical reflection the small size of the animals allowed one to say with certainty only that they flew considerably above 500' AGL.

Subsequent radar observation of what we presumed to be the emergence of these bats revealed that the pattern of emergence varied considerably with regard to details but exhibited the following general pattern. At 1845 (15 minutes before sunset) a small dot located at the approximate position of the bat cave appeared on the search radar both with and without the MTI circuits in operation. Fifteen minutes later at about sunset the dot had expanded to a heart shaped cloud about seven miles across. Lowering the radar antenna angle of inclination to two degrees gave maximum size and density of the cloud; raising the antenna to six degrees gave a much smaller cloud with open spaces in it. At this time the altitude portion of the PAR system was just able to detect a series of dots at its outer limit at about 1000' AGL. On three nights at this time radar installation at the San Antonio International Airport was asked if they could also detect what we thought were bats; despite their complete disbelief the first time we asked, they reported a similar concentration of "clutter" in the same area we did. One night at this time two aircraft flying through the area reported seeing "bunches" of bats in flight. The first aircraft was an Air Force plane which had been alerted by our radar personnel and reported seeing bats at 1000' AGL when flying over the area of the cave.

FAA personnel at San Antonio had apparently taken an interest in our work as the second report was relayed by them from a civilian aircraft flying over the area at 1500'. We do not know the type of aircraft or whether the pilot had been alerted by the FAA personnel. Fifteen minutes after sunset the cloud had increased in size to about 15 miles across and was less dense in the center near the cave than at the perimeter. On one occasion the cloud assumed a configuration termed by the radar operators a J hook and said to be characteristic of tornadoes as seen on radar. By 1930 the cloud had expanded to a diffuse ring as much as 20 miles across. From this time to 1945 the level of clutter on the radar scope increased so as to make the cloud difficult to discern. We suspect that this clutter resulted from the dispersion of additional flying animals over the area. We have no way of knowing at the present whether these were bats or migrating birds.

Visual observations from a helicopter

We were fortunate in having a double rotor fire rescue helicopter at our disposal for one evening. We were able to observe parts of the serial dispersal pattern of the Mexican Free-tailed bats emerging from the Bracken Cave at dusk and to make a brief sampling of the density of flying animals at night at various altitudes.

Observations from the helicopter of bats emerging from their cave were coordinated with ground observers at the cave and the above described radar installation of the base. The helicopter was first positioned directly above the opening of the cave at 500' AGL and its position marked on the radar scope. The "cloud" (see above) observed on radar that night originated less than one mile from the entrance of the cave. Ground observers at the cave that night reported that flocks of bats emerged from the cave mouth and flew just above tree level E-SE for about one mile and then ascended out of sight. The bats emerged from the cave for only 34 minutes, although three nights before the animals were still flying out of the cave after one hour and 15 minutes. (A cold front had passed through the area between the two observations which may have precipitated a migration of the animals to warmer areas). Observation of flying bats from the helicopter proved to be difficult particularly in fading light or against the ground; in addition only the pilots had a clear view in front of the aircraft while the authors could see clearly only out the side.

Attempts to closely follow flocks of bats proved unsuccessful as the bats easily outmaneuvered the helicopter. Observation of the emergence pattern from about one-half mile revealed flights of bats ascending rapidly at about one mile from the cave. In attempting to visually follow these flights we repeatedly saw bats well above the aircraft when we were 1000' AGL. At first the pilots attempted to maneuver around flocks of bats. We soon found it better to maintain course at low speed as the bats would disperse

in front of the approaching helicopter keeping at least 25 feet from the rotors (no animals were pulled down through the rotors). With the danger to the helicopter thus reduced, we were directed by radar observers to areas of presumed maximum density of bats. In general, the density of bats observed in fading twilight from the helicopter agreed with that predicted by radar observers. We encountered flocks of bats most commonly between 500' and 1500' although at least one bat was seen at 2000' AGL. We often saw 20-30 bats within 100' of the helicopter, but the maximum density of the animals during this phase of flight may well be greater as the radar observers reported that whenever they tried to direct us to the densest areas of the bat "cloud", the area immediately around the helicopter would become relatively clear.

The density of flying animals at night was roughly determined at a point topographically similar to the base but eight miles NE of Randolph. The search lights of the helicopter were directed forward at about 45 degrees to the horizontal. The helicopter forward speed was kept at about 40 mph and all the bats passing through a well lighted, roughly cylindrical area about 50 feet x 100 feet in a two minute period were counted. The actual beam of the searchlight proved to be too narrow for our purposes and the area lighted by scatter from the searchlight beam was used instead. Thus the figures represent the approximate number of animals in about 35×10^6 cu.ft. Bats flew erratically and usually alone, birds appeared as clusters of ten or more flying straight through the light beam and insects appeared as points of light without wings. It was often difficult to tell a bat from a lone bird and the bat detectors were useless as the helicopter generated much high frequency noise. These results are given in Table 1.

TABLE 1

Flying Animals seen from a Helicopter in a Two Minute Period (see text for explanation).

Altitude AGL	No. of Bats	No of Birds	No. of Insects
200'	more than 30	none seen	many
300'	more than 30	none seen	many
500'	26	none seen	many
500'	24	none seen	many
1000'	23	rare	many
1500'	about 20, some may have been birds	2-3 flocks	not as many as at 1000'

2,000'	less than 10	5 + flocks	rare
2,500'	rare	many flocks of small birds	rare

Discussion

To the best of our knowledge this is the first instance of radar targets having been positively identified as bats. In addition, our observations have established with certainty that bats fly at relatively great altitudes, at least 2000' AGL, although many observers have estimated from visual observation from the ground that these animals fly at 2500' to 10,000'. Documentation of these reports is of great interest since the echolocation employed by bats for orientation at lower altitudes could not possibly be operative at these heights.

Tentative Recommendations

The night sky during the period of our observations seemed to be heavily populated with the Mexican Free-tailed bats from ground level to 1500', these animals being replaced by birds above 2000'. Around lights the density of bats is increased by the addition of a second species, probably Myotis velifer. We were fortunate in being able to observe both birds and bats but we suspect that birds would constitute the major hazard to aircraft during the late fall and early spring while bats would predominate during the summer nights. Since the vast majority of these animals originate from areas not under Air Force control and often far removed from the base (there being hundreds of bats roosts and caves in the San Antonio area alone), and since the vast majority of "birdstrikes" occur off of the base, bird or bat control on the base, although perhaps desirable for other reasons, would not seem to be of significant value in reduction of "birdstrikes". Neither does it seem that turning off lights near the runways would substantially affect the accident rate of night flying aircraft.

We do, however, feel that much might be done to identify areas in which the concentrations of flying animals pose an increased hazard. Much of the information needed for warning pilots of such areas is readily available but until recently was not used. Radar operators at Randolph Air Force Base are now able to inform pilots that they may be flying through an especially dense concentration of bats. Even our very brief visit has identified one type of such concentration and we feel certain that other concentrations of flying animals can be identified by radar or other means. Neither is the problem restricted to the Air Force. Pilots in the San Antonio area have told us that FAA personnel are at present alerting pilots when they see the most obvious signs of birds in migratory flocks, that is a V of dots slowly moving across the radar screen. This information is not transferred from one radar installation to another in an orderly

way nor is any record of these observations kept for more than 30 days. Research with radar in other parts of the world indicates that more complex radar echoes can be recognized as flying animals. Thus, further investigation of the area at different times of the year might well identify areas and altitudes which for brief periods represented an extreme danger to aircraft. Our visual observations of the Mexican Free-tailed bats emerging from the Bracken Cave (only one of several in the area) indicate this as one such area. Flocks of bats from this cave are so dense that as many as ten or twenty animals could certainly be ingested by a single jet engine of an aircraft flown through the flock; this mass of animal matter would pose a hazard to even the large, heavy engines of commercial aircraft. The danger, however, exists for only about one hour and is highly localized and we feel, is observable on radar.

We also concur with the recommendations of the Flying Safety Division of Air Training Command at Randolph that modification of the most susceptible aircraft would undoubtedly reduce the hazard of "birdstrikes".

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13. ABSTRACT

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The distribution of the Mexican Free-tailed bat during the night at ground level seems to be constant in all locations tested in and near the base; concentrations of a second species of bats, probably Myotis velifer occur around strong lights which attract insects.

Mexican Free-tailed bats emerging from the Bracken Cave near the base do so in dense clusters of 100-1000 animals; some of these bats fly at least 2000'AGL. Some of these bats or clusters of bats are identifiable on MPN 16 Radar, and areas of maximum concentration can be detected.

At night in late October the concentration of bats from ground level to 1500' averages about one bat/million cubic feet. Above 1500'the concentration of birds increases.

It is our opinion that much information regarding the density of flying animals is presently available through radar systems and that this information, if utilized, would be of vital importance to aircraft.

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